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On Foundation Treatment for Old Houses and Factory Buildings

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SYNOPSIS This article is for the participation in the discussion on papers under Theme I presented at the International Conference on Case Histories in Geotechnical Engineering and can be regarded as additional information to Theme I. A few cases of foundation treatment for old residential houses and factory buildings are enumerated, whereby engineering problems are studied to find solutions. It is held that a solution that can be suited to a case and also costeffective should be selected in the light of the nature of a building and its foundation. It is of the opinion that the solution with drilled or excavated pile (pier) foundation is more suitable for the foundation treatment of old houses and factory buildings because it is advantageous in loadbearing and the control of vibration and noise, and little in the interference with the existing structure. The viewpoint of the author has been expounded through these practical examples.

INTRODUCTION

As is well known, to upgrade production and increase economic benefits , old factories are often subject to modifications to tap their potentialities. As a result, projects of a revamp and expansion nature are increasing daily . Furthermore , some old factory buildings need to be reinforced and renovated. For an old city to take on a new look more quickly to meet the need of city development and housing condition improvement, quite a few old residential houses call for a higher rise and additional storeys so as to increase architectural area. This is advantageous to saving construction area needless to occupy any farming land and to reduce investment as the existing utilities can be made full use of . In the modification to an old factory or the addition of new storeys to an old house, foundation treatment, however, is one of the key technical problems to be tackled. Therefore it's of pronounced importance to discuss and study the subject matter by means of case histories .

PRELIMINARY STUDY AND PRACTICE

There are some generalities in the foundation treatment for both modification to old faclories and addition of new storeys to old houses. For example., houses crowding together, space shortage, existing buildings preferably not to be dismantled for reconstruction, nearby buildings and structures not to be interfered with, underground pipe network criss-crossing, facilities for foundation treatment difficult to operate, and every effort to be made to treat the foundation with the production still going on or the resident still using the house , etc. Furthermore geological conditions must be respected and only the measures to suit them can be taken. Actual conditions of a project impose strict restrictions on the choice of treatment ways and means . Therefore whether a foundation can be treated , how it can be treated and whether the treatment can be a success or a failure depends on the treatment method and the facilities used. Wuhan Foundation Engineering Center has had some studies and practices in connection with projects , some of which will now be cited as examples.

1. Foundation treatment in case of modification to an old factory . Modification to old factories breaks down mainly into two categories . One is something has gone so wrong with the foundation of an old factory that normal production is affected or it is difficult to meet the need of production development , The other is modernization of the technological process and equipment in an old factory entails reconstruction or expansion of the building.

The foundation treatment we conducted for the highgrade cigarette workshop in a cigarette factory is just an example of the first category . The building of this workshop is 30mx 36m in plan and 12m in column spacing . The column spacing along the walkway in the workshop is 6m. It's of reinforced concrete frame structure, braced truss and prefabricated floor slab being 12m, and with brick wall enclosure . It was originally designed as a two-storey building for production purpose . After being put into service , a third storey was added due to production expansion . Consequently uneven settling occurred. The middle column foundation , close to which there happened to be cellars and channels , was subject to bigger load . Its settlement thus amounted to as much as 52 mm. Actual settlement of an individual foundation and difference in settlement between foundations , however , were even higher as at the initial stage no observation and measuring work had ever been done for the settling . The fact that the structure was more sensitive to settling resulted in extensive cracks. The middle column of the ground floor presented a deformation of torsional failure . The ground in this area obviously caved in. There were also serious cracks in all the members of main and secondary trusses at all levels , crack width averagely more than 1mm, max. 4mm, and with fast propagation , too. Cracks on the inner wall were max. 1cm wide. Door frame deformed. This endangered the structural safety and affected production and it was thus taken as an emergency project for treatment. Considering this workshop had a very high output value, it was requested by the factory leadership to have it reinforced without production shutdown.

To ascertain the causes of column foundation settling and structure cracking, the geological condition was reprospected . Engineering geological section is shown in Fig. 1.

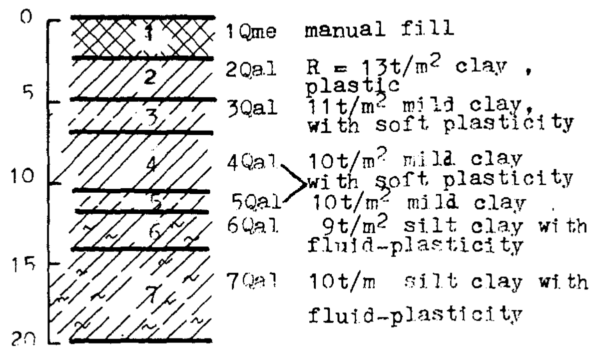

Fig. 1. Geological section of the cigarette factory

It can be seen from the analysis of soil quality and load that: (a) The porosity of the foundation soil is big, liquidity index relatively high, compressibility relatively high , load-bearing capacity relatively low , and pressure on the foundation bottom exceeds the allowable load-bearing capacity after the correction of foundation soil. (b) It was said that the embedment depth of the foundation had been adjusted to suit the geological condition. But it was not possible to excavate it for examination because production was still going on. In view of the fact that the fill was as thick as 2.8m, additional settling would result easily if any filled soil remained beneath the foundation bottom. (c) Before it was constructed cellars and channels had been built there , the bottom level of which was -5.0m whereas that of the column foundation for the building , which was constructed later and very close to them , was only -3.8m. But no suitable measure had ever been taken to counter this. This also accounts for the uneven settling. (d) This building is of a sensitive nature. Uneven settling soon caused cracks in columns, trusses and wall.

In view of the cruxes of the problem in the building , rescue treatment was conducted for the middle four column foundations while measures were taken to reinforce the upper structure by steelwork . From stress point of view , the damage of middle columns and their trusses and the settling of foundation had a direct bearing on the safety of the whole building structure and the use of the building for production. The first thing, therefore, was to treat the middle column foundation. The treatment was to have the load borne by the pile foundation. Around each column foundation were arranged 9 concrete piles cast in the holes drilled. The pile was 550mm in diameter and 15m in length. An integral pile supporting block , which was connected with the coarsened lower part of a column, was provided to undertake the load of the upper structure (Fig. 2). After the treatment , settling remains stable and the building serves well for the production . Due to the arrangement for maintenance and repair , the column foundations on four sides of the building were not treated for the time being, but no further problems were found .

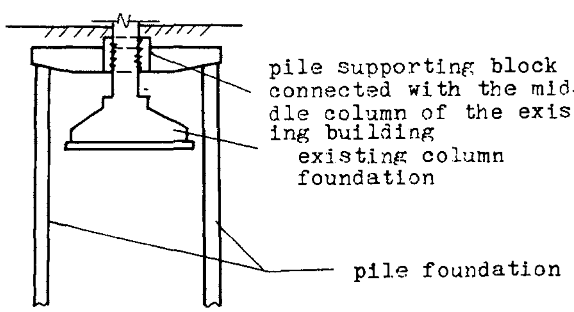

Fig. 2. Schematic diagram of the treatment for middle column foundation

Half a year later , the piling for a new building in the vicinity of the old one, set off new settling of the not yet treated side column foundations and new cracks in the structure . To counter this , new columns were provided outside the wall to take over the load of all storeys originally transmitted onto the wall and side columns . Beneath the columns , piles were added. This not only ensured reliability in loadbearing without affecting production , but also made it easier to drill holes for casting piles.

The foundation treatment of a sintering plant for modification falls into the second category. In this project , new and old parts of the structure and production equipment had to be made dovetail and existing pipelines crisscrossed. It was therefore very difficult to arrange pile foundation for the expanded and modified parts according to normal practice. In some cases , there was no room for a pile. The water supply mains for the whole plant , which ran through the expansion area , was required not to be interfered with in the slightest degree. Old and new equipment foundations overlapped, and very short overhaul time tolerated no dismantlement of the old one before constructing a new one. The solution in this case, therefore, was to "stick in" a pile (or a pier) wherever there's room. Pile supporting blocks connected one another were made into "stools" of irregular shape to take over column load. For the foundation of a new machine , pits were dug in the vicinity of the old one to construct piers before hand , ready to receive the new machine to be rush-exchanged when overhaul period came.

2. Foundation treatment in the case of addition of storeys to an old house. In an expansion project involving two three-storey residential houses to have additional four storeys the solution was to add an outer frame system. In this way , the foundation and structure had a clearcut loadbearing. Furthermore the architectural design was treated accordingly, so that the old and new were combined and the two originally separate houses linked into one. This solution was not only safe and reliable but also enabled addition of more storeys to meet the housing requirement.

The two three-storey residential houses were of brick construction , with strip block stone masonry as the foundation. Being situated by an old pond, the foundation soil was not even in quality. Beneath the bottom of the foundation was old fill and silt mild clay, 2-6m thick , [R]= 10-13t/m^2. Still down under was clay , [R]= 30t/m . The columns of the added outer frame were kept against the wall surface. Under each column were provided 3 to 4 ∅500mm, 8-15m long piles.

There are the following features and requirements as defined by the actual condition of this project: (A) To carry out the foundation treatment without removing the households : (B) Drilling for pile cast-in must be done very close (only 33cm) to the old wall foundation because the frame columns are kept against the old wall surface. The old wall foundation is actually on the large side , so the block stone masonry at the edge still needs to be chiseled off before constructing piles. (C) In the course of the treatment , the load-bearing condition of the foundations for the existing structures must be kept as usual to avoid new settling and cracking in the upper structure. (D) There are water supply and sewerage pipes embedded on all sides of the old structure. The pilework, therefore , is required not to damage the water pipes so that they can still be in good service, in addition to satisfying the position, quantity and length of the pile as required by the load of the upper structure. To realize this, coordination work is needed. (E) The principle is not to change pile location rashly, but instead , to have the filled soft soil, cave-ins and underground stone blocks properly treated to ensure pile foundation quality. (F) There is narrow and limited space available between structures. The equipment for constructing pile foundation, therefore, should be adaptable , flexible in moving and safe in operation. (G) Water supply and drainage for construction need is difficult, and supplementary technical measures must be taken . (H) Vibration, noise and polution must be kept to a minimum.

In the light of the a.m. engineering features and requirements, obviously it's not suitable to install piles by means of strike-in, vibration, or static pressure, etc. Piles were therefore made by means of casting in holes drilled at site. Where soil condition was good and the wall of drilled hole could be self-supporting , a self-made big bolt was used to drydrill a hole into which concrete was poured directly. Where soil condition was bad and there was underground water so that the wall of a drilled hole could not be self-supporting , submerged wet-drilling was used and concrete was poured from under water so that work could progress without delay (Fig. 3).

Fig. 3. The work site of the foundation treatment for two houses to be added with new storeys and combined into one

Three pile group tests were conducted at site to test the single pile static load bearing limit. The results were 180t, 160t and 150t, respectively. This shows the need of addition of storeys to the old house has been met, and the foundation treatment has achieved initial success. It can be seen from the economic result of this soltion that the construction cost to add a number of storeys to an old house is slightly higher than that to build a new one with the same numbe of storeys. However, the former has the advantag in saving land cost. From technical point of view the solution and pilemaking method applied has met the special requirement of the project. Thus the problem of adding storeys to an old hou in a city has been initially solved.

To go further into this problem, the foundation engineering for an office building is another ex ample worth studying. This building was designe to have seven storeys. However when 6 storeys we completed half a year after starting constructio by means of raft integral foundation , relativel big settling had resulted and the house had been much out of perpendicular. The construction ha to stop. Measured values were : $S_{max} = 40.4$cm , $\Delta S_{max} = 21.6$cm, $\tan\alpha_{max} = 0.016$. The structur tilted to the street. Deflection at the top was 42 cm and was still developing, posing danger to the use of the house and public safety . Whether the seventh storey was to be built was all the more a problem. The three-storey houses next to both sides of the building suffered a great deal , with cracks resulting from pulling force at the two ends connected with the building. Households removed (Fig. 4).

Fig. 4. The settling and leaning of the building causing damage to the neibouring house

The main reason why such a big settling and tilting resulted is the foundation soil quality was very poor. Under the foundation bottom were sundry fill, silt and humus containing soft clay respectively from above . Soil quality was uneven and the soil layer was not well distributed . The allowable load-bearing capacity of the foundation was very low ,(R) = 0.4-0.9 kg/cm^2, E_s = 15-34 kg/cm^2. Not being properly treated , the sundry fill and silt layer in particular , failed to meet the designed load requirement . The fact that a mass of bricks were once piled up at the border on the street made the situation even worse.

Our solution to the problem in this case was to support the load of the structure by pile foundation and to rectify the leaning by dead weight.

PRELIMINARY IDEAS ON THE APPROACH TO THE PROBLEM

The foundation treatment in the case of modification to an old factory or addition of new storeys to an old house is subject to restrictions imposed by the actual condition and features special requirements. It is therefore a subject to be approached from different angles and practices. The cases cited above are only for initial study. A thorough understanding of the subject calls for further exploration . Here below are a few opinions of mine:

1. Full account should be taken of the settlement and its effects to be controlled for a building being a combination of old and new when selecting a foundation treatment solution. This is often an important factor for success or failure in the treatment. Moreover , consideration should be given to the requirement of loadbearing capacity and the foundation characteristics. Effort should be made to suit a remedy to the situation, and to ensure that a solution is simple, effective , and reasonable from technical and economic point of view.

2. Our initial exploration shows that the solution of pile or pier foundation type is reliable and effective in the modification to old houses and factory buildings where it is required to take over relatively big load .

3. The way to drill or excavate holes for pile (pier) cast-in is little in vibration, noise and the influence on existing buildings, and therefore suitable for the modification to old houses and old factories. It's obvious that the treatment method depends on facilities in use . They should be simple and convenient, flexible , smaller in size but higher in capacity, and free to move and operate. This is especially important in the case of setting up piles within an old house or between equipments is an old factory.

4. For sludge removal and water drainage, It's necessary to develop a sludge and water handling vehicle to keep the treatment site clean and tidy.

In general, every country, every project has its own characteristics and conditions . Therefore for us geotechnical scientists, it is necessary to attach importance to engineering practice and to study successful or unsuccessful cases unceasingly. Only in this way, can relatively suitable solutions be found to various complicated geotechnical engineering problems facing us. This is the only way to make encouraging progresses in this field.